Commercial Reusable Launch Vehicle (CRLV) Technology Roadmap Study

Sponsored by the NASA Innovative Partnership Program (IPP), and the Air Force Research Laboratory (AFRL)

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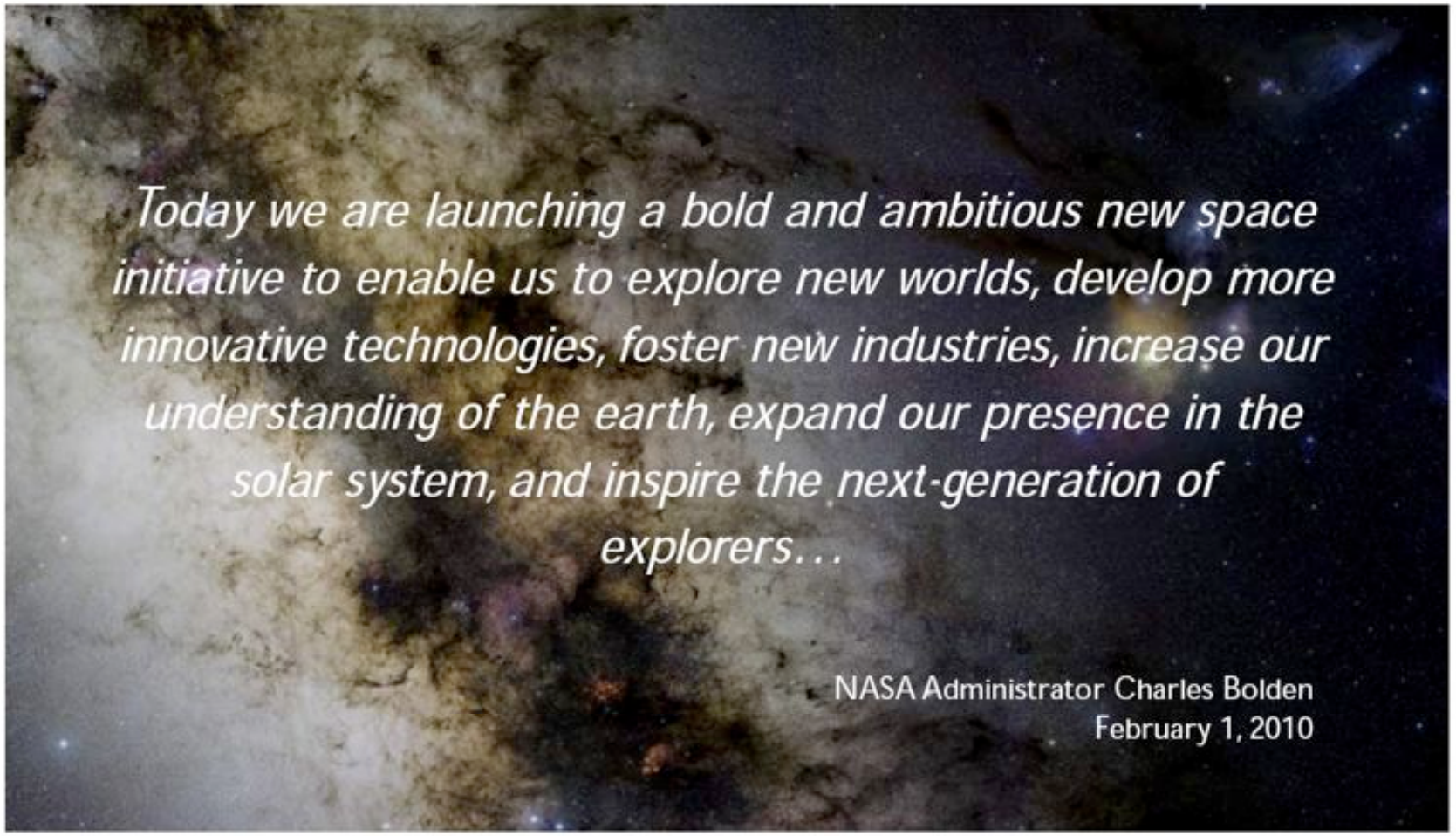
Path Forward



Space Technology

	2011	2012	2013	2014	2015
Space technology	$572	$1,012	$1,060	$1,064	$1,218

- Funds advancements in next-generation technologies, to help improve the Nation's leadership in key research areas, enable far-term capabilities, and spawn game-changing innovations to make NASA, other government and commercial space activities more capable and affordable.

- Involves a broad array of participants including academic, commercial and international partnerships and incorporates the current Innovative Partnerships Program (including the Small Business Innovative Research and Small Business Technology Transfer Research programs.)

- Focuses on key areas, such as communications, sensors, robotics, materials, and propulsion.

- Uses prizes and other innovative research funding mechanisms, in addition to grants and other more traditional funding mechanisms.

Commercial Crew and Cargo

	2011	2012	2013	2014	2015
Commercial Crew	$500	$1,400	$1,400	$1,300	$1,200
Commercial Cargo	$312	--	--	--	--

- Building off successful progress in the development of commercial cargo capabilities, the Budget invests $6 billion over five years to spur the development of American commercial human spaceflight vehicles.
- NASA will allocate these funds through competitive solicitations that support a range of higher- and lower-programmatic risk systems and system components, such as human-rating of existing launch vehicles and development of new spacecraft that can ride on multiple launch vehicles. NASA will ensure that all systems meet the agency's stringent human-rating requirements.
- In addition, to these commercial spaceflight amounts, the Budget provides (only in FY 2011) $312 million for additional incentives for NASA's current domestic commercial cargo service providers.

1. Critical Technology Demonstrations

	2011	2012	2013	2014	2015
Exploration Tech and Demo	$652	$1,262	$1,808	$2,013	$2,087

- Led by NASA's Exploration Directorate, components include:
  - *Flagship demonstration program:*
    - Pursues projects that are generally funded at $0.4-$1.0 billion over lifetimes of less than 5-years, and that can include partnerships with international, commercial and other government entities.
    - Demonstrates critical technologies such as in-orbit propellant transfer and storage, inflatable modules, automated/autonomous rendezvous and docking, closed-loop life support systems, and other next-generation capabilities.
  - *Enabling technology development program:*
    - Pursues smaller scale (less than $100 million generally) and shorter duration projects that are competitively selected and also can involve commercial, academic, and international partners.
    - Demonstrates a broad range of key technologies, including in-situ resource utilization and advanced in-space propulsion.

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NASA ANNOUNCES COMMERCIAL RLV TECHNOLOGY ROADMAP PROJECT

WASHINGTON -- NASA is partnering with the U.S. Air Force Research Laboratory to develop a technology roadmap for the commercial reusable launch vehicle, or RLV, industry.

"NASA is committed to stimulating the emerging commercial reusable launch vehicle industry," said Lori Garver, deputy administrator at NASA Headquarters in Washington. "There is a natural evolutionary path from today's emerging commercial suborbital RLV industry to growing and developing the capability to provide low-cost, frequent and reliable access to low Earth orbit. One part of our plan is to partner with other federal agencies to develop a consensus roadmap of the commercial RLV industry's long-range technology needs."

The study will focus on identifying technologies and assessing their potential use to accelerate the development of commercial reusable launch vehicles that have improved reliability, availability, launch turn-time, robustness and significantly lower costs than current launch systems. The study results will provide roadmaps with recommended government technology tasks and milestones for different vehicle categories.

"Low-cost and reliable access to space will deliver significant benefits to all NASA's existing missions, from science to human exploration to aeronautics, as well as to our nation's security and to national economic growth," said Doug Comstock, director of NASA's Innovative Partnerships Program at NASA Headquarters. "Part of our plan is to apply lessons learned from the recent past and also the great successes of the National Advisory Committee for Aeronautics in stimulating the American commercial airplane industry nearly 100 years ago."

Objective:

- *Study will focus on identifying technologies and assessing their relative utility for enabling future space access capabilities*
- **Primary Goal:** Accelerating development of Commercial Reusable Launch Vehicles (CRLV's)
- **Performance Goals:**
  - Significantly lower cost
  - Improved reliability, availability, launch turn-time
  - And improved robustness compared to current launch systems

CRLV Technology Roadmap

Anticipated Key Technologies:

- *Entry, Descent and Recovery Systems, and Advanced TPS*
- *Propulsion, OMS and ACS*
- *Structures and Materials*
- *Avionics, Communications and Flight Control*
- *Vehicle (Internal) Energy & Thermal Management Systems*
- *Life Support and Safety Systems*
- *On-orbit Operations and Equipment*
- *Ground Support, Operations and Processing Equipment*
- *Advanced Concept Technologies*

Team

The Team that will perform this work is made up of:

- *Oversight: Doug Comstock/NASA, Charles Miller/NASA, Minoo Dastoor/NASA, Bruce Thieman/AFRL, Thomas Jacobs/AFRL*
- *Leads: Dan Rasky/NASA & Walter Glance/AFRL*
- *Technical Support – NASA: Joe Shaw/GRC, David Hunstman/GRC, Julie Fowler/LaRC, Ron Merski/LaRC, John Kelly/DFRC, Russ Barber/DFRC, Mark Nall/MSFC, David Stephenson/MSFC, Bruce Morris/MSFC, William Hosler/JSC, Brian Hall/WFF, Lloyd Eldred/LaRC, Brian Hollis/LaRC, Brian Jensen/LaRC, Hyun D.Kim/GRC, Sungwan Kim/LaRC, Roger Lepsch/LaRC, David Manzella/GRC, Kevin Melcher/GRC, Ajay Misra/GRC, Mark Newfield/ARC, Hugh Perkins/GRC, Jill Prince/LaRC, Sai Raj/GRC, Charles Smith/ARC, Charles Trefny/GRC, William Winfree/LaRC, James Yuko/GRC, Gregor Hanuschak/ARC, Jennifer Cole/DFRC, Bruce Pittman/ARC, Tony Ginn/DFRC, Bruce Webbon/ARC, Raj Ventekapathy/ARC*
- *Technical Support – AFRL: Nils Sedano, Jeremy Andrews, Jeffrey V. Zweber*
- *Technical Support – FAA: Nick Demidovich, Michelle Murray*

Approach

- **Four categories of space access vehicles being considered:**
  1. *Reusable, sub-orbital vehicles (e.g., Virgin Galactic, Blue Origin, XCOR, Masten, Armadillo, Rocket Plane, etc.)*
  2. *Expendable and partially reusable, orbital vehicles (e.g., SpaceX, Orbital, etc.)*
  3. *Reusable, two-stage orbital vehicles (e.g., Kistler)*
  4. *Advanced vehicle concepts (e.g., single stage to orbit, air-breathing systems, in-flight refueling, tethered upper stage, ...)*
- **NASA/USAF began the study by soliciting feedback from the emerging commercial space industry about technologies that would most benefit their existing and near-term vehicle systems**
- **Initial inputs obtained from one-on-one interviews with 19 companies at the CRASTE 2009 conference, October 26-29, 2009**

Approach (Cont.)

- NASA/USAF will add to the initial list technologies needed for advanced vehicle concepts, as well as longer range technologies needed for the first three vehicle categories
- For this work NASA/AFRL will draw upon agency expertise as well as vehicle systems studies and analyses
- NASA/USAF will then evaluate the combined inventory of needed technologies an capabilities and sort them with respect to their value for accelerating CRLV development
- Where possible, current NASA/USAF programs investing in needed technologies and capabilities will be noted
- The Sandia Technology Roadmapping Structure/Approach (SAND97-0665) is being used for Roadmap development

Company Interviews

To date 28 companies interviewed:

- **Small (< 100 employees)**
  - Advent Launch Systems, Andrews Space (on-site), Armadillo Aerospace, Astrox, Barron Associates, Ce Dev, Firestar Engineering (on-site), Garvey Spacecraft Corporation, Go Hypersonics, Masten Space Systems (on-site), Orion Propulsion, Spaceworks Engineering, TGV Rockets, XCOR (on-site)
- **Medium (100 - 1000)**
  - Blue Origin (on-site), Microcosm Inc., Orbitec, Scaled Composites (on-site), Sierra Nevada, SpaceX (on-site)
- **Large (> 1000)**
  - ATK, Boeing, Lockheed Martin, Raytheon, Pratt & Whitney, United Launch Alliance, Vought Aircraft

Planned additional interviews & visits:

- Orbital Sciences (on-site), Aerojet, KT Engineering, Rocketplane

Preliminary Results -
Company Identified Needs

Four Principle Need Areas Identified:

1. ***Business Support***
2. ***Government Services***
3. ***Integrated Flight Demonstrator(s)***
4. ***Specific Technologies***

Preliminary Results -
Company Identified Needs

Business Support	# Companies
1 - Help to stimulate and support new customers, including small payloads & their integration	*8*
2 - Help to maintain/increase specialized hardware and component suppliers	*4*

Preliminary Results -
Company Identified Needs

Government Services	# Companies
1 - Provide responsive, affordable access to government facilities and equipment (e.g. wind-tunnels, rocket test stands, arc-jets, large cryo-tank tooling)	*13*
2 - Allow easier access with improved user support to government specialized space-vehicle design software	*12*
3 - Help provide range operation simplification, automation and standardization, in-particular for small launch systems, and including daily atmospheric data support and vehicle hazard assessments	*11*
4 - Provide responsive, affordable access to government subject area experts	*10*
5 - Develop and make available government standards, databases and reports for space-vehicle and subsystem design, testing, operation and failures	*7*
6 - Help with removal of dangerous orbital debris	*2*

Preliminary Results -
Company Identified Needs

Integrated Flight Demonstrator(s)	# Companies
Sponsor integrated, reusable, flight demonstrator(s) for advanced technology integration, and operational methods development	*16*

Preliminary Results -
Company Identified Needs

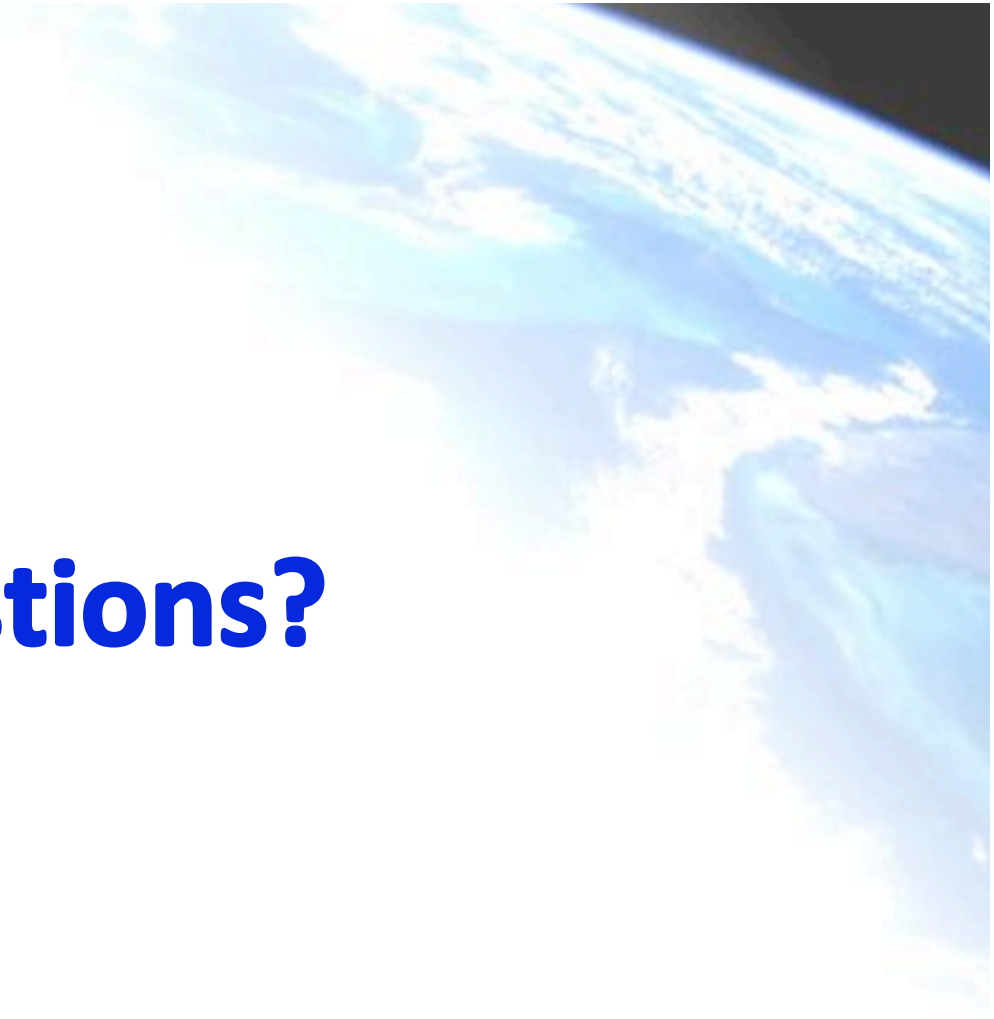
Specific Technologies	# Companies
Propulsion and Cryogenics	*32*
1 - Develop and characterize more operable fuels for ACS, RCS and vacuum APS, including very small thrusters	8
2 - New high-temperature materials and advanced designs for turbo pumps, advanced injectors, thrust chambers and nozzles	5
3 - Low cost thrust vector control	4
4 - Advanced cyrogenic seals, valves and bellows	3
5 - Advanced cyro fluid management systems	2
6 '- Reduce/eliminate ordinance weight and complexity	2
7 - Characterization of LOX/Methane engines and development of improved LOX/Methane fuels	2
8 - Low cost pressurized systems for propulsion	2
9 - Large (~450 klb) and small (50-100 klb) class LOX/RP engines for rocket boosters	2
10 - Subsonic combustion ramjets for accelerator missions (high T/W rather than maximizing ISP)	1
11 - Reusable rocket motor cases	1
Avionics and Vehicle Electronics	*22*
1 - Develop advanced avionics, including autonomous flight, adaptive flight control and IVHM	15
2 - Advanced sensors and wireless systems for vehicle data acquisition, control and power	4
3 - Automated tools for analysis and verification of complex electronic circuits / programmable logic	1
4 - Methods for rapid incorporation of state-of-the-art electronics in space systems	1
5 - Powerful and light-weight space qualified batteries	1

Preliminary Results -
Company Identified Needs

Specific Technologies (Cont.)	# Companies
Entry Systems and TPS	*17*
1 - Operable TPS with automated inspection, and rapid repair and recertification	13
2 - Hardware entry, descent and recovery techniques, including air-snatch, vertical landing and ocean recoveries	4
Materials and Structures	*17*
1 - Advanced, non-autoclave composites for structures and tankage, including linerless LOX and composite over-rap metallic tanks, and tank failure characterization	8
2 - New light-weight, high-temperature, high-performance materials and composites for structures, including fatigue testing, material compatibility and allowables, and predictive failure methods	7
3 - Light-weight landing gear	2
Ground Processing and Operations	*16*
1 - Operational methods for inspection, repair and recertification of space hardware, including ISHM and advanced sensors	13
2 - Rapid/real time mission planning tools	3
Crew Systems and In-Flight Operations	*7*
1 - Crew systems & human factors including g-limits, ECLSS, and automated flight safety systems	4
2 - Standard on-orbit docking systems and procedures	3

Products

- Roadmaps with recommended government technology tasks and milestones will be compiled and documented, along with initial budget and resource requirement estimates
- Initial roadmaps will be constructed by February, 2010
- These will be reviewed and refined by an independent review panel of distinguished experts in space transportation systems
- Final Roadmaps will be published in May 2010



Questions?

Backup Slides

Funding Table

Budget Authority ($M)	FY 2009	ARRA	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Science	**4,503.1**	**400.0**	**4,493.3**	**5,005.6**	**5,248.6**	**5,509.6**	**5,709.8**	**5,814.0**
Earth Science	1,377.3	325.0	1,420.7	1,801.7	1,944.4	2,089.4	2,216.5	2,282.1
Planetary Science	1,288.1		1,341.3	1,485.8	1,547.3	1,591.3	1,630.2	1,649.5
Astrophysics	1,229.9	75.0	1,103.9	1,076.3	1,109.3	1,149.1	1,158.7	1,131.6
Heliophysics	607.8		627.4	641.9	647.6	679.8	704.4	750.8
Aeronautics and Space Research and Technology	**500.0**	**150.0**	**507.0**	**1,151.8**	**1,596.9**	**1,650.1**	**1,659.0**	**1,818.2**
Aeronautics Research	500.0	150.0	507.0	579.6	584.7	590.4	595.1	600.3
Space Technology				572.2	1,012.2	1,059.7	1,063.9	1,217.9
Exploration	**3,505.5**	**400.0**	**3,779.8**	**4,263.4**	**4,577.4**	**4,718.9**	**4,923.3**	**5,179.3**
Space Operations	**5,764.7**		**6,180.6**	**4,887.8**	**4,290.2**	**4,253.3**	**4,362.6**	**4,130.5**
Space Shuttle	2,979.5		3,139.4	989.1	86.1			
International Space Station	2,060.2		2,317.0	2,779.8	2,983.6	3,129.4	3,221.9	3,182.8
Space and Flight Support (SFS)	725.0		724.2	1,119.0	1,220.6	1,123.9	1,140.7	947.7
Education	**169.2**		**183.8**	**145.8**	**145.8**	**145.7**	**145.7**	**146.8**
Cross-Agency Support	**3,306.4**	**50.0**	**3,095.1**	**3,111.4**	**3,189.6**	**3,276.8**	**3,366.5**	**3,462.2**
Center Management and Operations	2,024.3		2,067.0	2,273.8	2,347.4	2,427.7	2,509.7	2,594.3
Agency Management and Operations	921.2		941.7	837.6	842.2	849.1	856.8	867.9
Institutional Investments	293.7	50.0	23.4					
Congressionally Directed Items	67.2		63.0					
Construction and Environ. Compliance and Restor.			**448.3**	**397.3**	**363.8**	**366.9**	**393.5**	**398.5**
Inspector General	**33.6**	**2.0**	**36.4**	**37.0**	**37.8**	**38.7**	**39.6**	**40.5**
NASA FY 2010	**17,782.4**	**1,002.0**	**18,724.3**	**19,000.0**	**19,450.0**	**19,960.0**	**20,600.0**	**20,990.0**
Year to Year Change			*5.3%*	*1.5%*	*2.4%*	*2.6%*	*3.2%*	*1.9%*

4

The IPP program has been transferred from CAS to Space Technology in FY 2011. The FY 2009 and FY 2010 amounts are $160 million and $175 million respectively. FY 2010 funding levels may also change, subject to approval in NASA's initial operating plan.

The law that created NASA, the National Aeronautics and Space Act of 1958, as amended, gives NASA an <u>often overlooked</u> mission.

NASA's founding legislation states that we will "seek and encourage, to the maximum extent possible, the fullest commercial use of space."

Remarks by the NASA Administrator
Gen Charles Bolden

National Association of Investment Companies
Washington DC, October 20, 2009